

# ON A POSSIBILITY OF SCALAR GRAVITATIONAL WAVE DETECTION FROM THE BINARY PULSAR PSR 1913 + 16

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## ABSTRACT

It is shown that detecting or setting an upper limit on the scalar gravitational radiation is a good experimental test of relativistic gravity theories. The relativistic tensor-field theory of gravitation is revised and it is demonstrated that the scalar monopole gravitational radiation must be added to the usual quadrupole radiation. In the case of the binary pulsar PSR 1913 + 16 it is predicted the existence 0.735% excess of the gravitational radiation due to the scalar gravitational waves.

## 1. Scalar Gravitational Radiation as a Test of Gravity Theories

### 1.1. Geometry of Spacetime or Quantum Field in Flat Spacetime

Gravitational wave experiments give us a new possibility in choosing among alternative gravity theories. Here we revise nonmetric tensor-field theory (TFT) of gravitation, i.e. relativistic theory of symmetrical second rank field  $\psi^{ik}$  in flat Minkowski spacetime  $\eta^{ik}$  and compare its gravitational wave predictions with general relativity (GR) ones.

It is easy to show that widespread opinion on full coincidence of TFT and GR (see for example<sup>1</sup>) based on the assumption of the uniqueness of the energy-momentum tensor (EMT) of the gravitational field, which was used for the iteration procedure. However, in the framework of Lagrangian formalism of relativistic field theory, EMT of any field is not defined uniquely:  $T^{ik} \Rightarrow T^{ik} + \Phi^{ikl}{}_{,l}$  for  $\Phi^{ikl} = -\Phi^{ilk}$  (see for example<sup>2,3</sup>), and one needs additional physical restrictions to choose final form of the EMT (for example such conditions as energy positiveness, tracelessness, symmetry). It is apparently that different EMTs will lead to different nonlinear theories of gravitation.

To illustrate the above-said discussion let us consider nonlinear generalization of Poisson's equation for the case of distributed source describing negative and positive energy density of the gravitational field

$$\Delta\varphi = -(\nabla\varphi)^2/c^2, \quad (1a)$$

and

$$\Delta\varphi = +(\nabla\varphi)^2/c^2. \quad (1b)$$

The solution of Eq.1a is

$$\varphi = c^2 \ln \left( 1 - \frac{GM}{c^2 r} \right), \quad \frac{d\varphi}{dr} = \frac{GM}{r^2 (1 - GM/c^2 r)}; \quad (2)$$

whereas the solution of Eq.1b is

$$\varphi = -c^2 \ln \left( 1 + \frac{GM}{c^2 r} \right), \quad \frac{d\varphi}{dr} = \frac{GM}{r^2 (1 + GM/c^2 r)}. \quad (3)$$

From Eq.2 and Eq.3 we see two possible ways for the construction of the nonlinear TFT. The first one, based on the negative energy density of the gravitational field, leads to the infinite gravity force at the finite distance  $R_g = GM/c^2$ . The second way, based on positive one, gives TFT without singularity.

As for GR, the energy density of the gravitational field is a poorly defined concept as a consequence of geometrical interpretation of gravity (there is no tensor characteristic of the gravitational field EMT). For example, Landau-Lifshitz pseudotensor gives  $t^{00} = -7(\nabla\varphi_N)^2/8\pi G$  but Grischuk-Petrov-Popova one gives  $t^{00} = -11(\nabla\varphi_N)^2/8\pi G$  for the spherically symmetric static (SSS) weak field in harmonic coordinates.

Within the scope of TFT there is a real tensor quantity for the energy density of the gravitational field. For example canonical EMT gives  $T^{00} = +(\nabla\varphi_N)^2/8\pi G$  for SSS weak field and corresponds quantum description of the gravitational field as aggregate of gravitons in flat spacetime. Gravitons are massless particles, i.e. some kind of matter in spacetime, which carry-over positive energy and momentum in the spacetime. Besides the sum of two tensors  $\psi^{ik} + \eta^{ik} = g^{ik}$  is not a metric tensor because the covariant components  $\psi_{ik} + \eta_{ik} = g_{ik}$  of this tensor provide the mixed components  $\psi_k^i + \eta_k^i = g_k^i \neq \delta_k^i$  and the trace  $g^{ik}g_{ik} = 4 + 2\psi + O(\psi_{ik}^2) \neq 4$ . It means that TFT is a scalar-tensor theory, but not pure tensor one, and hence includes spin 2 and spin 0 gravitons.

## 1.2. Post-Newtonian Tensor-Field Theory of Gravitation

Let us consider the relativistic symmetric tensor field  $\psi^{ik}$  in Minkowski's spacetime  $\eta^{ik}$ . As so as really observed gravitational fields are the weak ones ( $|\varphi| \ll c^2$ ), it is naturally to begin the construction of TFT for the weak field case. In this case we have a very closed analogy with the electromagnetic field and can use the standard

Lagrangian formalism of the relativistic field theory (bellow we utilize notations of the text-book<sup>2</sup>).

We begin with the action integral in the form

$$S = S_{(g)} + S_{(int)} + S_{(p)} = \frac{1}{c} \int (\Lambda_{(g)} + \Lambda_{(int)} + \Lambda_{(p)}) d\Omega \quad (4)$$

where  $(g)$ ,  $(int)$  and  $(p)$  indicate gravitational field, interaction and particles parts of actions and Lagrangians. The Lagrangians are given by the following expressions

$$\Lambda_{(g)} = -\frac{1}{16\pi G} [2\psi_{nm}{}^{,n}\psi^{lm}{}_{,l} - \psi_{lm,n}\psi^{lm,n} - 2\psi_{ln}{}^l\psi^{,n} + \psi_{,l}\psi^{,l}], \quad (5)$$

$$\Lambda_{(int)} = -\frac{1}{c^2}\psi_{lm}T_{(p)}^{lm}, \quad (6)$$

$$\Lambda_{(p)} = -\eta_{ik}T_{(p)}^{ik}. \quad (7)$$

It has been shown by Kalman<sup>4</sup> and Thirring<sup>5</sup>, that the total EMT of the system contains three parts, which correspond to ones of the action integral (4),

$$T_{(\Sigma)}^{ik} = T_{(p)}^{ik} + T_{(int)}^{ik} + T_{(g)}^{ik} \quad (8)$$

where the canonical EMT of the gravitational field for Lagrangian (5) has the form

$$T_{(g)}^{ik} = \frac{1}{8\pi G} \left\{ (\psi^{lm,i}\psi_{lm}{}^{,k} - \frac{1}{2}\eta^{ik}\psi_{lm,n}\psi^{lm,n}) - \frac{1}{2}(\psi^{,i}\psi^{,k} - \frac{1}{2}\eta^{ik}\psi_{,l}\psi^{,l}) \right\} \quad (9)$$

the interaction EMT is

$$T_{(int)}^{ik} = \frac{2}{c^2}T_{(p)l}{}^i\psi^{lk} - \frac{1}{c^2}T_{(p)}^{ik}\psi_{lm}u^lu^m, \quad (10)$$

the point particles EMT is

$$T_{(p)}^{ik} = \sum_a m_a c^2 \delta(\mathbf{r} - \mathbf{r}_a) \left\{ 1 - \frac{v_a^2}{c^2} \right\}^{1/2} u_a^i u_a^k. \quad (11)$$

Therefore the nonlinear TFT must include the interaction Lagrangian in the form

$$\Lambda_{(int)} = -\frac{1}{c^2}\psi_{lm}T_{(\Sigma)}^{lm}. \quad (12)$$

But the weak field condition allows us to use linear approximation as the first step and then to make nonlinear corrections (Post-Newtonian TFT).

The variation of the gravitational potentials in the action integral (4), where for fixed sources in the PN approximation we can use the interaction Lagrangian (12), yield the PN field equations in the form

$$-\psi^{ik,l}{}_l + \psi^{il,k}{}_l + \psi^{kl,i}{}_l - \psi^{,ik} - \eta^{ik}\psi^{lm}{}_{,lm} + \eta^{ik}\psi_{,l}{}^l = \frac{8\pi G}{c^2} T_{(\Sigma)}^{ik} \quad (13)$$

Eq.13 automatically requires conservation of the total EMT and leads to the particles motion equations in the form  $T_{(\Sigma),k}^{ik} = 0$ .

The field equations are invariant (for fixed sources) under the gauge transformation  $\psi^{ik} \Rightarrow \psi^{ik} + \theta^{i,k} + \theta^{k,i}$  and one can achieve Hilbert gauge in the form:  $\psi^{ik}_{,k} = \frac{1}{2}\psi^{,i}$ . In this case the field Eq.13 become

$$\square\psi^{ik} = \frac{8\pi G}{c^2} \left[ T_{(\Sigma)}^{ik} - \frac{1}{2}\eta^{ik}T_{(\Sigma)} \right]; \quad (14)$$

The very important feature of Eq.13 is the multi component structure of the gravitational field description. Initial symmetric tensor  $\psi^{ik}$  simultaneously describes a mixture of four particles

$$\{\psi^{ik}\} = \{2\} \oplus \{1\} \oplus \{0\} \oplus \{0'\} \quad (15)$$

with spins equal 2, 1, 0 and  $0'$ . It corresponds to 10 independent components of the tensor  $\psi^{ik}$ . After four gauge conditions, Eq.14 describes a mixture of two particles which have two sources

$$\{\psi^{ik}\} = \{2\} \oplus \{0\} \Leftrightarrow \{T^{ik}\} = \{2\} \oplus \{0\} \quad (16)$$

So that eq.(14) can be written in the form

$$\square\psi_{\{2\}}^{ik} = \frac{8\pi G}{c^2} T_{\{2\}}^{ik} \quad \text{or} \quad \square\phi^{ik} = \frac{8\pi G}{c^2} \left[ T_{(\Sigma)}^{ik} - \frac{1}{4}\eta^{ik} T_{(p)} \right] \quad (17a)$$

and

$$\square\psi_{\{0\}}^{ik} = -\frac{8\pi G}{c^2} T_{\{0\}}^{ik} \quad \text{or} \quad \frac{1}{4}\square\psi\eta^{ik} = -\frac{8\pi G}{c^2} T_{(p)} \frac{1}{4}\eta^{ik} \quad (17b)$$

where  $\psi^{ik} = \psi_{\{2\}}^{ik} + \psi_{\{0\}}^{ik} = \phi^{ik} + \frac{1}{2}\eta^{ik}\psi$  (and the same representation for  $T_{(\Sigma)}^{ik}$ ), besides we take into account that gravitons of both kinds are massless particles, i.e. have traceless EMTs ( $T_{(\Sigma)} = T_p$ ).

The variation of action integral (4) with respect to particle coordinates gives the equation of motion in the gravitational field<sup>4, 7</sup>

$$A_k^i \frac{du^k}{ds} = -B_{kl}^i u^k u^l \quad (18)$$

where

$$A_k^i = \left( 1 - \frac{1}{c^2} \psi_{ln} u^l u^n \right) \eta_k^i - \frac{2}{c^2} \psi_{kn} u^n u^i + \frac{2}{c^2} \psi_k^i, \quad (19)$$

$$B_{kl}^i = \frac{2}{c^2} \psi_{k,l}^i - \frac{1}{c^2} \psi_{k,i}^l - \frac{1}{c^2} \psi_{kl,n} u^n u^i. \quad (20)$$

### 1.3. Static Weak Field

In the case of spherically symmetric static (SSS) weak field the first approximation EMT has a very simple form  $T_{(\Sigma)}^{ik} = \text{diag}(\rho_0 c^2, 0, 0, 0)$  and solution of Eq.14 is Birkhoff's potential

$$\psi^{ik} = \varphi_N \text{diag}(1, 1, 1, 1), \quad (21)$$

where  $\varphi_N$  is Newtonian potential ( $\varphi_N = -GM/r$  outside the gravitating body).

The gravitational field (21) can be expressed as the sum of the spin 2 and spin 0 parts

$$\psi^{ik} = \psi_{\{2\}}^{ik} + \psi_{\{0\}}^{ik} = \varphi_N \text{diag}(\frac{3}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}) + (-\varphi_N) \text{diag}(\frac{1}{2}, -\frac{1}{2}, -\frac{1}{2}, -\frac{1}{2}). \quad (22)$$

Using the SSS solution (21) and corresponding EMT expressions (9), (10), (11) we find the total energy densities of the system from Eq.8

$$T_{(\Sigma)}^{00} = T_{(p)}^{00} + T_{(int)}^{00} + T_{(g)}^{00} = (\rho_0 c^2 + e) + \rho_0 \varphi_N + \frac{1}{8\pi G} (\nabla \varphi_N)^2 \quad (23)$$

where  $(\rho_0 c^2 + e)$  is the rest mass and the kinetic energy densities,  $\rho_0 \varphi_N$  is the interaction energy density,  $\nabla \varphi_N^2 / 8\pi G$  is the energy density of the gravitational field. The total energy of the system will be

$$E_{(\Sigma)} = \int T_{(\Sigma)}^{00} dV = E_0 + E_k + E_p \quad (24)$$

where  $E_0 = \int (\rho_0 c^2) dV$  is the rest-mass energy,  $E_k = \int (e) dV$  is the kinetic energy, and  $E_p$  is the classical potential energy that equals the sum of the interaction and the gravitational field energy:

$$E_p = E_{(int)} + E_{(g)} = \int (\rho_0 \varphi_N + \frac{1}{8\pi G} (\nabla \varphi_N)^2) dV = \frac{1}{2} \int \rho_0 \varphi_N dV \quad (25)$$

It is important to note that the canonical EMT (9) include both EMTs for spin 2 and spin 0 gravitons. Hence the  $T_{(g)}^{00}$  given by (9) is the sum of energy densities of both components (see for details<sup>6</sup>).

For external field of SSS body in PN approximation the only needed correction is to take into account the energy density of the gravitational field. Hence we have exactly Eq.1b and nonlinear addition for Birkhoff's  $\psi^{00}$  component is

$$\psi^{00} = \varphi_N + \frac{1}{2} \frac{(\varphi_N)^2}{c^2}. \quad (26)$$

Substituting Birkhoff's potential (21) into (18) and taking into account non-linear PN correction (26) one gets the three dimensional equation of motion for test particle

$$\frac{d\mathbf{v}}{dt} = -\left(1 + \frac{v^2}{c^2} + 4\frac{\varphi_N}{c^2}\right) \nabla \varphi_N + 4\frac{\mathbf{v}}{c} \left(\frac{\mathbf{v}}{c} \cdot \nabla \varphi_N\right). \quad (27)$$

For Eq.27 the pericenter shift of test particle is

$$\delta\phi = \frac{6\pi GM_0}{c^2 a(1-e^2)}, \quad (28)$$

in which the nonlinear contribution (26) provides 16.7% of the value (28). Therefore in TFT there is a direct testing of the positive energy density of the gravitational field.

It is easy to show<sup>5, 6, 7</sup> that all PN classical relativistic gravitational effects have the same values as in GR but the other interpretations. For example substituting Eq.22 in Eq.18 one finds that usual Newtonian force is the sum of the attracting force (spin 2) and repulsing force (spin 0)

$$F = F_{\{2\}} + F_{\{0\}} = -\frac{3}{2}m_0\nabla\varphi_N + \frac{1}{2}m_0\nabla\varphi_N = -m_0\nabla\varphi_N = F_N \quad (29)$$

#### 1.4. Free Field

Within the scope of TFT not only static, but also variable gravitational field contains the sum of spin 2 and spin 0 gravitons. The field equations in the form (17), can be written for the free field as

$$\square\phi^{ik} = 0, \quad \phi^{ik}_{,k} = 0 \quad (29a)$$

and

$$\frac{1}{4}\square\psi\eta^{ik} = 0. \quad (29b)$$

Eqs.29 can be derived from the free field Lagrangians

$$\Lambda_{\{2\}} = \frac{1}{16\pi G}\phi_{lm,n}\phi^{lm,n}, \quad (30a)$$

and

$$\Lambda_{\{0\}} = \frac{1}{64\pi G}\psi_{,n}\psi^{,n}. \quad (30b)$$

Eqs.30 is a consequence of the gravitational field Lagrangian (5) for the field connected with sources (full field equations (13)). Note that sign of (30b) is positive due to positive energy density condition for spin 0 free particles. Corresponding EMTs for tensor (spin 2) and scalar (spin 0) gravitational waves are

$$T_{\{2\}}^{ik} = \frac{1}{8\pi G}\phi_{lm}^{,i}\phi^{lm,k}, \quad (31a)$$

and

$$T_{\{0\}}^{ik} = \frac{1}{32\pi G}\psi^{,i}\phi^{,k}. \quad (31b)$$

## 2. Emission of Tensor and Scalar Gravitational Waves

Let us consider the retarded potentials solution of Eqs.17 in the wave zone for slow motions in the source. For Eq.17a we have usual quadrupole radiation (spin 2 gravitons) with luminosity

$$L_{\{2\}} = \frac{G}{45c^5} \ddot{D}_{\alpha\beta}^2 \quad (32)$$

where  $D_{\alpha\beta}$  is the reduced quadrupole moment of the system of particles.

In the same conditions the solution of the Eq.17b is

$$\psi(\mathbf{r}, t) \approx \frac{2GM_0}{r} - \frac{2GE_k}{c^2 r} + \frac{2GM_0}{cr} (\mathbf{n} \cdot \dot{\mathbf{R}}) + \frac{G}{c^2 r} n_\alpha n_\beta \ddot{I}_{\alpha\beta}, \quad (33)$$

where  $M_0 = \sum m_a$  is the rest mass,  $E_k = 1/2 \sum m_a v_a^2$  is the kinetic energy,  $\mathbf{R} = \sum m_a \mathbf{r}_a / \sum m_a$  is the center of mass,  $I_{\alpha\beta} = \sum m_a x_a^\alpha x_a^\beta$  is the moment of inertia of the system. Differentiation with respect to the time of Eq.33 leaves the only monopole term

$$\dot{\psi}(\mathbf{r}, t) \approx -\frac{2G\dot{E}_k}{c^2 r} \quad (34)$$

because the first term equals to zero in consequence of rest mass conservation, the third term equals to zero in view of inertial motion of the center of mass and the fourth term vanishes so that it has been taken into account within quadrupole radiation (32). Substituting Eq.34 into scalar wave EMT (31b) and averaging it on the sphere one gets the scalar monopole luminosity (spin 0 gravitons)

$$L_{\{0\}} = \frac{G}{2c^5} \dot{E}_k^2 \quad (35)$$

## 3. Detection of Tensor and Scalar Gravitational Waves

### 3.1. Test Particles in Tensor Wave

Let us consider inertial frame of reference where we analyzed action integral (4) and derived equations of motion for test particles (18). We can fix Cartesian coordinates with being the gravitational radiation source in the origin and the  $x$ -axis along propagation of gravitational wave. For plane tensor wave  $\phi^{ik}$  satisfying Eq.29a the only nonzero components are  $\phi^{22} = -\phi^{33} = A_+$  and  $\phi^{23} = \phi^{32} = A_\times$ , where for monochromatic wave  $A(t, x) = A^0 \cos(\omega t - kx)$ . Substituting above expressions into Eq.18 and leaving the main terms one gets equation of motion of test particle in the plane monochromatic tensor wave

$$\frac{dv_x}{dt} = 0 \quad \text{and} \quad \begin{cases} \frac{dv_y}{dt} = 2v_y \frac{\dot{A}_+}{c^2} + 2v_z \frac{\dot{A}_\times}{c^2} \\ \frac{dv_z}{dt} = 2v_y \frac{\dot{A}_\times}{c^2} - 2v_z \frac{\dot{A}_+}{c^2} \end{cases}. \quad (36)$$

It follows from Eq.36 that the tensor wave is transversal, i.e. there is no acceleration along propagation direction. Besides for the rest test particle ( $v_x = v_y = v_z = 0$ ) there is no interaction between particle and tensor wave (in a manner like the rest charged particle has no interaction with magnetic field in electrodynamics). Therefore in the case of tensor gravitational wave the velocity of test particle plays the role of “gravitational charge” and we need such detectors in which there is system of particles with nonzero relative velocities. For example it may be rotating bodies and even metallic bars where the degenerate electrons have nonzero velocities relatively crystallic proton lattice. The amplitude of the velocity deviation can be estimated as  $\Delta v = 2vA/c^2$ .

### 3.2. Test Particles in Scalar Wave

For the scalar plane monochromatic gravitational wave satisfying Eq.29b we have  $\psi_{\{0\}}^{ik} = A(t, x)\eta^{ik} = A^0 \cos(\omega t - kx)\eta^{ik}$ . If we substitute this expression into Eq.18 and leave the main terms we get the following equation of motion of test particle in scalar wave

$$\frac{dv_x}{dt} = c \frac{\dot{A}}{c^2} \quad \text{and} \quad \begin{cases} \frac{dv_y}{dt} = 0 \\ \frac{dv_z}{dt} = 0 \end{cases}. \quad (37)$$

According to Eq.37 the scalar wave is longitudinal and the rest test particle oscillates around initial position with the velocity amplitude  $\Delta v = cA/c^2$  and the distance amplitude  $\Delta x = A/kc^2$ . For two particles at a distance  $l_0 \ll \lambda$  along x-axis we get the dimensionless amplitude of oscillation in the form  $\Delta l_0/l_0 = A/c^2$ . Hence the detection of the scalar wave can be achieved by means of bar detectors and laser interferometric detectors. It is important to note that scalar gravitational wave does not interact with the electromagnetic field because the interaction Lagrangian is  $\psi_{(0)}^{ik} T_{ik} = \frac{1}{4} \psi \eta_{ik} T_{(em)}^{ik} = 0$ .

## 4. Binary Pulsar PSR 1913+16

### 4.1. Gravitational Radiation from Binary System

For a binary system the loss of energy due to tensor gravitational radiation is given by Eq.32. Direct calculations lead to the well-known formula for quadrupole luminosity of the binary system

$$\langle \dot{E} \rangle_{\{2\}} = \frac{32G^4 m_1^2 m_2^2 (m_1 + m_2) \left(1 + \frac{73}{24}e^2 + \frac{37}{96}e^4\right)}{5c^5 a^5 (1 - e^2)^{7/2}}, \quad (38)$$



where  $m_1, m_2$  are masses of the two bodies,  $a$  is the semimajor axis and  $e$  is eccentricity of the relative orbit. The similar calculations based on Eq.35 give the loss of energy due to scalar monopole radiation<sup>8</sup>

$$\langle \dot{E} \rangle_{\{0\}} = \frac{G^4 m_1^2 m_2^2 (m_1 + m_2) \left( e^2 + \frac{1}{4} e^4 \right)}{4c^5 a^5 (1 - e^2)^{7/2}}, \quad (39)$$

The ratio of the scalar (39) to the tensor (38) luminosity is

$$\frac{\langle \dot{E} \rangle_{\{0\}}}{\langle \dot{E} \rangle_{\{2\}}} = \frac{5}{128} \cdot \frac{\left( e^2 + \frac{1}{4} e^4 \right)}{\left( 1 + \frac{73}{24} e^2 + \frac{37}{96} e^4 \right)}. \quad (40)$$

Note that the value of the ratio (40) lies in the interval  $[0, 1.1\%]$  and for the circular orbit equals to zero. However for a pulsating spherically symmetric body there is no quadrupole radiation and scalar radiation becomes decisive. In particular it follows from this that in the TFT it is impossible to have a “quiet” relativistic collapse of a spherical body.

#### 4.2. PSR 1913 + 16

According to<sup>9,10</sup> for the binary pulsar PSR 1913 + 16 the eccentricity  $e = 0.6171309(6)$ , hence the expected scalar radiation part (40) is 0.735 %. As far as the rate of orbital period change  $\dot{P}$  is proportional to the total energy loss ( $\langle \dot{P} \rangle = -\frac{3}{2} \frac{\dot{E}}{P} < \dot{E} >$ ), one expects the corresponding excess of orbital period decrease due to scalar gravitational radiation. The observed value of the orbital period change is<sup>10</sup>

$$\dot{P}^{(\text{obs})} = -2.425(10) \cdot 10^{-12},$$

while the theoretical prediction for pure tensor quadrupole radiation is<sup>9</sup>

$$\dot{P}_{\{2\}}^{(\text{theor})} = -2.402576(69) \cdot 10^{-12}.$$

Therefore the observed excess of the orbital period decrease is

$$\left( (\text{Obs}) - (\text{Theor}) \right) = +0.96 \% \pm 0.4 \%$$

that is very close to the expected value 0.735 % for the scalar gravitational radiation. Taking into account the spin 0 part (39) of the gravitational radiation we get the theoretical prediction

$$\dot{P}^{(\text{theor})} = \dot{P}_{\{2\}}^{(\text{theor})} + \dot{P}_{\{0\}}^{(\text{theor})} = -2.420254(69) \cdot 10^{-12}$$

in a good agreement with the observed value.

#### 4.3. Problem of Galactic Acceleration

It has been shown in<sup>9</sup> that one must take into account the effect of the galactic acceleration of the pulsar and the Sun, and that of the proper motion of the pulsar. Note that the distance  $d$  to PSR 1913 + 16 is the very sensitive parameter for the calculation of the galactic effect. Unfortunately the line of sight to the pulsar pass through very complex region of our Galaxy and one must be very careful to use known distances to other pulsars for distance estimation to PSR 1913 + 16. Indeed in<sup>9</sup> it was used indirect arguments to re-estimate the standard dispersion-measure distance of 5.2 kpc and to get the new distance of 8.3 kpc. For the  $d = 8.3$  kpc the galactic effect is +0.69 %. However another arguments<sup>11</sup> based on an analysis of the pulse structure of PSR 1913+16 itself lead to an estimation of the distance about 3 kpc. For the  $d = 3$  kpc the galactic effect is +0.11 %. In any case it is clear that we need further investigation of the pulsar and the direct estimation of the distance to PSR 1913 + 16.

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